PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Combustion Equipment of Gas-Turbine Engines

We, ROLLS-ROYCE LIMITED, a British Company, of Nightingale Road, Derby, in the County of Derby, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention comprises improvements in or relating to combustion equipment of gas-turbine engines, and the invention is applicable to combustion equipment of the kind comprising a series of flame tubes, each in an individual tubular air casing, to combustion equipment of the kind comprising a series of flame tubes disposed within an annular space between coaxial annular air casing walls, and to combustion equipment of the kind comprising an annular flame tube coaxially within an annular space between coaxial annular air casing walls.

This invention has for an object to secure improved combustion of fuel in such combustion equipment.

According to the present invention, in combustion equipment of a gas-turbine engine of the kind comprising a flame tube or flame tubes and an air casing or air casings, there is provided first means to introduce fuel and air into a first region of the flame tube adjacent its upstream end (considered in the general direction of flow through the combustion equipment) in a manner to produce a swirling motion in one direction, the fuel and air being substantially in their stoichiometric ratio, and second means to introduce fuel and air into a second region of the flame tube just downstream of the first region in a manner to produce a swirling motion in the opposite direction. It is found that by adoption of the invention improved combustion is achieved.

Preferably the first means is located at the local centre line of the flame tube and is adapted to cause the fuel/air mixture in the first region to flow from the point of introduction towards the walls of the flame tube, then upstream, then inwards towards the local centre line and then in the downstream direction, and the second means is arranged to cause at least the air introduced into the second region first to flow towards the centre line, then upstream, then towards the walls and then downstream.

Four embodiments of combustion equipment in which the fuel and air are delivered in accordance with this invention, will now be described with reference to the drawings accompanying the provisional specification, in which:—

Figure 1 shows in axial section a first embodiment;

Figure 2 is a similar view of a second embodiment, and

Figure 3 is a similar view of a third embodiment, and to the accompanying drawings, in which:—

Figure 4 is a similar view of a fourth embodiment, and

Figure 5 is a section on the line 5—5 of Figure 4.

Referring first to Figure 1, there is shown combustion equipment comprising a flame tube 10 arranged within a tubular air casing 11 so that there is an air passage around the flame tube.

The air casing 11 comprises a diffuser section 11*a* which is connected to compressor means (not shown) of the gas-turbine engine, and a main section 11*b* which extends from the diffuser section to the nozzle structure of the associated turbine (not shown).

The flame tube 10 comprises an upstream section 12 having an inlet 13 facing the entry of the diffuser section 11*a* of the air casing, and a downstream section 14 having in its walls large apertures 15 for the flow of air from the space between the flame tube 10 and

air casing 11 into the interior of the flame tube.

The upstream section 12 of the flame tube 10 has mounted within it a tubular member 16 with a domed end and this member defines the upstream end of the combustion space. The wall of the member 16 is generally parallel to the wall of the upstream section and is held in spaced relation thereto by a flange 17. Part of the air entering the flame tube through inlet 13 flows in the direction of arrow 18 between the walls of the upstream section 12 and the tubular member 16 to flow into the combustion space in the main through a ring of holes 20 formed in the tubular member 16 just upstream of the flange 17. A minor flow also occurs through apertures in the flange 17.

Mounted coaxially within the tubular member 16 and projecting into the combustion space are first means for introducing fuel and air into the combustion space. This means comprises a tube 21 which opens through the domed end of the tubular member to have an entry facing the inlet 13, which has a waisted portion so that the tube is of venturi form and which has secured to its downstream end a cap 22 having a frusto-conical side wall formed with a ring of holes 23. This means also comprises a spider having a hollow boss 24 coaxially within the tube 21 and a series of, say four, radiating tubular arms 25 which extend from the boss through the wall of the tube 21 upstream of its waist. The bore of the boss 24 has an entry facing the inlet 13 and the arms 25 afford air passages leading from the bore of the boss to externally of the tube 21. This means also comprises a fuel injector 26 supplied with liquid fuel by a conduit 27 and spraying fuel into the hollow boss 24. A frusto-conical baffle 29 is secured to the inner surface of the tubular member 16 to project towards the waist of the tube 21.

There is also provided second fuel and air injection means which is afforded in part by the holes 20 and in part by a fuel injector 28 projecting into the flame tube 10 and having an outlet orifice 30 injecting fuel in the upstream direction.

The injector 28 also has a downstream facing fuel orifice 31.

In operation, part of the air entering the diffuser section 11*a* flows through the inlet 13 and the remainder flows outside the flame tube 10 towards the apertures 15.

The air flowing through the inlet 13 flows (a) in part into the hollow boss 24, where fuel is sprayed into it, and the resulting air/fuel mixture then flows out through the arms 25 to be deflected by the baffle 29 along the outside of the tube 21, (b) in part through the tube 21 to the ring of holes 23 to be directed outwardly towards the wall of the tubular member 16, and (c) in part as shown by the arrow 18 towards the holes 20 and the flange 17.

The air/fuel mixture from the arms 25 and the air from the holes 23 combine in the combustion region 32 in a manner to produce a swirling motion as indicated by arrows 33, in which the mixture flows towards the wall of the tubular member 16, then in the upstream direction, then towards the tube 21 and then in the downstream direction. It is arranged that the fuel and air burning in the combustion region 32 are in their stoichiometric ratio.

The air entering the combustion space through the holes 20 and the fuel injected into the combustion space through the fuel orifice 30 combine in a combustion region 34 which is just downstream of the combustion region 32, in a manner to produce swirling motion which is in the opposite sense to the swirling motion in the region 32 and which is indicated by the arrows 35. Thus in the region 34 the motion of the burning air/fuel mixture is towards the centre line of the flame tube, then in the upstream direction, then towards the walls of the tubular member 16 and finally in the downstream direction.

The combustion products from the regions 32 and 34 flow downstream where further fuel is mixed with them from the orifice 31 to burn with excess air in the products and with air entering the combustion space through the apertures 15, which latter air additionally cools the combustion products.

It is found that by arranging the combustion to take place in adjacent regions in which swirling motions are produced in opposite senses, the combustion efficiency of the combustion equipment is improved.

Referring now to Figure 2, there is illustrated combustion equipment of the fully annular kind comprising inner and outer air casing walls 40 and 41 respectively and in the space between the air casing walls inner and outer annular flame tube walls 42 and 43 respectively. The walls 42, 43 are made in a number of sections and have adjacent their downstream ends large apertures 44 through which air flowing in the spaces between the inner walls 40, 42 and outer walls 41, 43 can enter the combustion space afforded between the flame tube walls 42 and 43.

The upstream edges of the flame tube walls 42, 43 are spaced apart to provide an air entry 45 to between these walls. Secured to the inner surface of the outer flame tube wall 43 and to the outer surface of the inner flame tube wall 42 there are annular air-flow dividing members 46, 47 respectively.

Each of the members 46, 47 is generally shaped to conform to the adjacent portions of the adjacent flame tube walls 43, 42 respectively and each is provided at its downstream end with a flange 48 by which it is attached to the associated flame tube wall and at its upstream end with an inturned flange 49 extending parallel to the axis of the combustion equipment, these flanges 49 being spaced

apart to form an air entry to between the annular members 46, 47. The annular members have formed in them just upstream of the flanges 48 rings of holes 50 by which air flowing between the annular members 46, 47 and the adjacent flame tube walls 43, 42 can enter the combustion space of the flame tube.

Extending radially between the annular members 46, 47 and secured to the downstream ends of the inturned flanges 49, there is an annular member of such section as to have a circumferential ridge 51 projecting downstream, which ridge closes the end of the passage between the flanges 49, and radially on each side of the ridge circumferential downstream facing troughs 52. The sides of the ridge are formed with rings of holes 51*a*.

Fuel is injected into the passage between the flanges 49 by means of an injector 53 fed with liquid fuel by a fuel supply pipe 54, and fuel is injected into the combustion space of the flame tube at a position just downstream of the annular members 46, 47 by means of an injector 55 having an upstream delivering fuel orifice 56 and a downstream delivering fuel orifice 57.

The fuel injector 53, the air passage between the flanges 49 and the annular member 51, 52 together afford first air and fuel injection means and the air/fuel mixture entering the upstream region 58 of the combustion space from the first air and fuel injection means partakes of a swirling motion as indicated by arrows 59, in which the mixture first travels from the local centre line of the flame tube towards the annular members 46, 47, then travels upstream, then travels towards the local centre line and finally travels downstream. It is arranged that the air and fuel introduced by the first air/fuel injection means are in their stoichiometric ratio.

The holes 50 in the annular members 46, 47 and the fuel injection orifice 56 together afford second air/fuel injection means which produce in a region 60 of the combustion space which is just downstream of the region 58, a swirling motion which is counter to the swirling motion in the region 58, that is the gases flow from the holes 50 towards the local centre line of the flame tube, then in the upstream direction, then away from the local centre line towards the annular members 46, 47 and then in the downstream direction. The fuel from the fuel orifice 57 mixes with the combustion products from the combustion zones 58, 60 and is burnt with the excess air therein and with air entering the combustion space through the apertures 44, which also mixes with the combustion gases to cool them.

Referring now to Figure 3, there is shown an arrangement which is similar to that shown in Figure 1 and similar parts in these figures are given the same reference numerals. However, instead of the spider member 24, 25 and fuel injectors 26, 28, an annular trough member 62 is provided to encircle the tube 21 adjacent its waist, the annular trough member 62 being concave on its downstream side and a single fuel injector 63 is provided for supplying fuel to both combustion regions. The injector 63 has a peripheral ring of fuel orifices 64 which inject fuel into the air which is flowing into the cap 22, prior to its entry into the upstream combustion space 65 through the holes 23 in the cap member and the injector 63 delivers fuel from its end 66 through an aperture in the cap member into the combustion region 67.

As in the construction of Figure 1 the combustion mixtures in the regions 65 and 67 have counter swirls as indicated by the arrows 33 and 35.

Referring now to Figures 4 and 5, there is illustrated a further form of combustion equipment which comprises an air casing having a diffuser section 70 and a main section 71, and a flame tube disposed within the air casing in spaced relation thereto, the flame tube being formed in a number of sections including an inlet section 72 and a section 73 having large air inlets 74 formed therein.

A tubular member 75 is fitted within the inlet section 72 of the flame tube, the tubular member being domed at its upstream end 75*a* and having an outward flange 75*b* at its downstream end, the flange 75*b* engaging the wall of the inlet section. The tubular member 75 has a ring of air inlet slots 89 in it adjacent the flange 75b. The domed end 75*a* of the tubular member 75 has a central inlet 76 facing an inlet 77 at the upstream end of the flame tube section 72, and a tube 78 having a waisted portion extends downstream from the inlet 76 into the interior of the flame tube. The tube 78 is provided at its downstream end with a frusto-conical skirted cap 79 having a series of slots 80 in its conical surface.

A hollow spider member 81 is fitted in the tube 78 adjacent its upstream end, the boss of the spider member having an inlet 82 facing the inlet 77; and the arms 81*a* of the spider member extend outwardly and pass through the wall of the tube upstream of its waisted portion to project into the interior of the flame tube just downstream of an annular trough member 83 which has its concave surface facing downstream. The arms 81*a* have outlets 84 at their outer ends, which outlets are in the form of tangentially-facing slots. Alternatively, the arms may have each a single tangentially facing slot, the slot facing in the same direction to cause a swirl about the axis of the flame tube.

Fuel is fed to the combustion equipment through a first pipe 85 leading to a nozzle 86 spraying into the spider member and through a pipe 87 leading to a second spray nozzle 88 which is mounted on the spider member and is arranged to produce a conical spray of fuel to pass out through the slots 80.

With this arrangement, first air and fuel injection means is afforded by the nozzle 86 and the spider 81 and partly by the slots 80. The air/fuel mixture entering the upstream region 90 of the combustion space is picked up by air from the slots 80 and is caused to swirl in the region 90 in the direction of arrows 91. It is arranged that the fuel and air burning in combustion region 90 are in their stoichiometric ratios.

The second air and fuel injection means is afforded by the nozzle 88 and the slots 89. The air from slots 89 swirls as indicated by arrows 93 in the region 92 of the combustion space in a direction contrary to the swirl in the region 90. The fuel from the nozzle 88 passes through the slots and enters the region 92 substantially tangential to the swirling mass of air from the slots 89 and in its passage through the slots 80 entrains a minor proportion of the air flowing through these slots.

In each construction an igniter device 95 is provided in the upstream region 32, 58, 65, 90.

In each of the constructions above described it is found that by arranging combustion to take place in separate and adjacent regions in which counter swirls are produced, the combustion efficiency of the apparatus is improved.

WHAT WE CLAIM IS:—

1. Gas-turbine engine combustion equipment of the kind comprising a flame tube or flame tubes and an air casing or air casings, wherein there is provided first means to introduce fuel and air into a first region of the flame tube adjacent its upstream end (considered in the general direction of flow through the combustion equipment) in a manner to produce a swirling motion in one direction, the fuel and air being substantially in their stoichiometric ratio, and second means to introduce fuel and air into a second region of the flame tube just downstream of the first region in a manner to produce a swirling motion in the opposite direction.

2. Gas-turbine engine combustion equipment according to Claim 1, wherein the first means is located at the local centre line of the flame tube and is adapted to cause the fuel/air mixture in the first region to flow from the point of introduction towards the walls of the flame tube, then upstream, then inwards towards the local centre line and then in the downstream direction, and the second means is arranged to cause at least the air introduced into the second region first to flow towards the centre line, then upstream, then towards the walls and then downstream.

3. Gas-turbine engine combustion equipment as claimed in Claim 1 or Claim 2, comprising air-flow dividing means fitted within the upstream end of the flame tube to define air passages between it and the flame tube extending part way along the length of the flame tube, said air passages having outlets from their downstream ends into the combustion space, said air-flow dividing means also defining an air inlet in the region of the local centre line of the flame tube, duct means projecting downstream from said inlet and having outlet holes into the combustion space upstream of the outlets from the air passages, the outlet holes delivering at least part of the air supply to the first region and the outlets from the air passages delivering at least part of the air to said second region.

4. Gas-turbine engine combustion equipment according to Claim 3, comprising also a hollow spider member having an upstream facing air inlet thereto and a series of radiating arms having outlets into said first region of the combustion space, and means to deliver liquid fuel into said hollow spider member to be conveyed with air flowing through the spider member and the arms thereof into said first region of the combustion space.

5. Gas-turbine engine combustion equipment according to Claim 4, comprising a fuel injector within said combustion space and spraying fuel upstream into said second region of the combustion space.

6. Gas-turbine engine combustion equipment according to Claim 4, comprising also a fuel injector within said duct means spraying fuel through said outlet holes into said second region of the combustion space.

7. Gas-turbine engine combustion equipment according to Claim 3, comprising means to inject fuel into air flowing in said duct means and entering said combustion space through said outlet holes thereby to supply fuel to said first region of the combustion space.

8. Gas-turbine engine combustion equipment according to Claim 7, comprising also a fuel injection nozzle within the combustion space and delivering fuel in the upstream direction into said second region of the combustion space.

9. Gas-turbine engine combustion equipment according to Claim 1, wherein the flame tube has fitted within it at its upstream end a tubular member having a domed upstream end and defining with the flame tube air passages extending lengthwise of the flame tube, which passages at their downstream ends have air outlets into the second region of the combustion space, said tubular member having in its domed end an air inlet, a tube mounted centrally of said tubular member and extending downstream from said inlet, said tube having at its downstream end air outlets into said first region of the combustion space, a hollow spider member accommodated within said tube adjacent its upstream end and having a hollow boss and hollow radiating arms extending through the wall of the tube to open into the combustion space adjacent said first region, means to inject fuel into said spider member to be carried by air flowing therethrough into said first region of the combus-

tion space, and means to deliver fuel into said second region of the combustion space.

10. Gas-turbine engine combustion equipment according to Claim 9, wherein said means to inject fuel into said second region of the combustion space comprises a fuel injector within the combustion space and downstream of said second region, said fuel injector being arranged to deliver fuel in the upstream direction into said second region.

11. Gas-turbine engine combustion equipment according to Claim 10, wherein said fuel injector is also arranged to spray fuel into the combustion space in a direction downstream from said second region.

12. Gas-turbine engine combustion equipment according to Claim 9, wherein the means to deliver fuel into the second region of the combustion space comprises a fuel injector supported by said spider and extending within said tube and arranged to spray fuel through the air outlets from the tube at an angle such that the fuel spray flows into the second region substantially tangentially of the swirling gases therein.

13. Gas-turbine engine combustion equipment according to Claim 1, wherein the flame tube has fitted within it at its upstream end a tubular member having a domed upstream end and defining with the flame tube air passages extending lengthwise of the flame tube which passages at their downstream ends have air outlets into the second region of the combustion space, said tubular member having in its domed end an air inlet, a tube mounted centrally of said tubular member and extending downstream from said inlet, said tube having at its downstream end air outlets into said first region of the combustion space, fuel injection means located within said tube and having first fuel orifices to direct fuel through said outlets to the first region of the combustion space and a further orifice directing fuel through an aperture in the downstream end of the tube into said second region of the combustion space.

14. Gas-turbine engine combustion equipment according to Claim 1, wherein the air casing and flame tube are of the fully annular kind, the flame tube having inner and outer annular walls, annular air-flow dividing members secured respectively to the inner surface of the outer wall and to the outer surface of the inner wall and defining between them and the flame tube walls air passages through which air flows in the downstream direction to air outlets into the second region of the combustion space, each of said annular air-flow dividing members having at its upstream end an inturned flange, said flanges defining between them an air duct on the local centre line of the flame tube, a member affording a pair of annular troughs separated by an annular ridge, which member extends between the annular air-flow dividing members and encloses the downstream end of the air duct, the troughs in said member facing downstream, holes in said annular ridge affording air outlets from the duct into the first region of the combustion space, a fuel injector delivering fuel into said air duct, and a second fuel injector within the combustion space downstream of the second region of the combustion space and arranged to direct fuel upstream into said second region.

15. Gas-turbine engine combustion equipment according to Claim 14, wherein said second fuel injector is arranged also to deliver fuel in the downstream direction.

16. Gas-turbine engine combustion equipment of the kind comprising a flame tube or flame tubes and an air casing or air casings, substantially as hereinbefore described with reference to and as illustrated in Figure 1 of the drawings.

17. Gas-turbine engine combustion equipment of the kind comprising a flame tube or flame tubes and an air casing or air casings, substantially as hereinbefore described with reference to and as illustrated in Figure 2 of the drawings.

18. Gas-turbine engine combustion equipment of the kind comprising a flame tube or flame tubes and an air casing or air casings, substantially as hereinbefore described with reference to and as illustrated in Figure 3 of the drawings.

19. Gas-turbine engine combustion equipment of the kind comprising a flame tube or flame tubes and an air casing or air casings, substantially as hereinbefore described with reference to and as illustrated in Figures 4 and 5 of the drawings.

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PROVISIONAL SPECIFICATION

Improvements in or relating to Combustion Equipment of Gas-Turbine Engines

We, ROLLS-ROYCE LIMITED, a British Company, of Nightingale Road, Derby, in the County of Derby, do hereby declare this invention to be described in the following statement:—

This invention comprises improvements in or relating to combustion equipment of gas-turbine engines, and the invention is applicable to combustion equipment of the kind comprising a series of flame tubes, each in an individual tubular air casing, to combustion equipment of the kind comprising a series of

flame tubes disposed within an annular space between coaxial annular air casing walls, and to combustion equipment of the kind comprising an annular flame tube coaxially within an annular space between coaxial annular air casing walls.

This invention has for an object to secure improved combustion of fuel in such combustion equipment.

According to the present invention, in combustion equipment of a gas-turbine engine of the kind comprising a flame tube or flame tubes and an air casing or air casings, there is provided first means to introduce fuel and air into a region of the flame tube adjacent its upstream end (considered in the general direction of flow through the combustion equipment) in a manner to produce a swirling motion in one direction, the fuel and air being substantially in their stoichiometric ratio, and second means to introduce fuel and air into a second region of the flame tube just downstream of the first region in a manner to produce a swirling motion in the opposite direction. It is found that by adoption of the invention improved combustion is achieved.

Preferably the first means is located at the local centre line of the flame tube and is adapted to cause the fuel/air mixture in the first region to flow from the point of introduction towards the walls of the flame tube, then upstream, then inwards towards the local centre line and then in the downstream direction, and the second means is arranged to cause at least the air introduced into the second region first to flow towards the centre line, then upstream, then towards the walls and then downstream.

Three embodiments of combustion equipment in which the fuel and air are delivered in accordance with this invention, will now be described with reference to the accompanying drawing, in which:—

Figure 1 shows in axial section a first embodiment;

Figure 2 is a similar view of a second embodiment, and

Figure 3 is a similar view of a third embodiment.

Referring first to Figure 1, there is shown combustion equipment comprising a flame tube 10 arranged within a tubular air casing 11 so that there is an air passage around the flame tube.

The air casing 11 comprises a diffuser section 11*a* which is connected to compressor means (not shown) of the gas-turbine engine, and a main section 11*b* which extends from the diffuser section to the nozzle structure of the associated turbine (not shown).

The flame tube 10 comprises an upstream section 12 having an inlet 13 facing the entry of the diffuser section 11*a* of the air casing, and a downstream section 14 having in its walls large apertures 15 for the flow of air from the space between the flame tube 10 and air casing 11 into the interior of the flame tube.

The upstream section 12 of the flame tube 10 has mounted within it a tubular member 16 with a domed end and this member defines the upstream end of the combustion space. The wall of the member 16 is generally parallel to the wall of the upstream section and is held in spaced relation thereto by a flange 17 which is apertured so that part of the air entering the flame tube through inlet 13 flows in the direction of arrow 18 between the walls of the upstream section 12 and the tubular member 16 to flow into the combustion space in the main through a ring of holes 20 formed in the tubular member 16 just upstream of the flange 17. A minor flow also occurs through the apertures in the flange 17.

Mounted coaxially within the tubular member 16 and projecting into the combustion space are first means for introducing fuel and air into the combustion space. This means comprises a tube 21 which opens through the domed end of the tubular member to have an entry facing the inlet 13, which has a waisted portion so that the tube is of venturi form and which has secured to its downstream end a cap 22 having a frusto-conical side wall formed with a ring of holes 23. This means also comprises a spider having a hollow boss 24 coaxially within the tube 21 and a series of, say four, radiating tubular arms 25 which extend from the boss through the wall of the tube 21 upstream of its waist. The bore of the boss 24 has an entry facing the inlet 13 and the arms 25 afford air passages leading from the bore of the boss to externally of the tube. This means also comprises a fuel injector 26 supplied with liquid fuel by a conduit 27 and spraying fuel into the hollow boss 24. A frusto-conical baffle 20 is secured to the inner surface of the tubular member 16 to project towards the waist of the tube 21.

There is also provided second fuel and air injection means which is afforded in part by the holes 20 and also comprises a fuel injector 28 projecting into the flame tube 10 and having an outlet orifice 30 injecting fuel in the upstream direction.

The injector 28 also has a downstream facing fuel orifice 31.

In operation, part of the air entering the diffuser section 11*a* flows through the inlet 13 and the remainder flows outside the flame tube 10 towards the apertures 15.

The air flowing through the inlet 13 flows (a) in part into the hollow boss 24, where fuel is sprayed into it, and the resulting air/fuel mixture then flows out through the arms 25 to be deflected by the baffle 29 along the outside of the tube 21, (b) in part through the tube 21 to the ring of holes 23 to be directed outwardly towards the wall of the tubular member 16, and (c) in part as shown by the

arrow 18 towards the holes 20 and the corrugated strip.

The air/fuel mixture from the arms 25 and the air from the holes 23 combine in the combustion region 32 in a manner to produce a swirling motion as indicated by arrows 33, in which the mixture flows towards the wall of the tubular member 16, then in the upstream direction, then towards the tube 21 and then in the downstream direction It is arranged that the fuel and air burning in the combustion region 32 are in their stoichiometric ratio.

The air entering the combustion space through the holes 20 and the fuel injected into the combustion space through the fuel orifice 30 combine in a combustion region 34 which is just downstream of the combustion region 32, in a manner to produce swirling motion which is in the opposite sense to the swirling motion in the region 32 and which is indicated by the arrows 35. Thus in the region 34 the motion of the burning air/fuel mixture is towards the centre line of the flame tube, then in the upstream direction, then towards the walls of the tubular member 16 and finally in the downstream direction.

The combustion products from the regions 32 and 34 flow downstream where further fuel is mixed with them from the orifice 31 to burn with excess air in the products and with air entering the combustion space through the apertures 15, which latter air additionally cools the combustion products.

It is found that by arranging the combustion to take place in adjacent regions in which swirling motions are produced in opposite senses, the combustion efficiency of the combustion equipment is improved.

Referring now to Figure 2, there is illustrated combustion equipment of the fully annular kind comprising inner and outer air casing walls 40 and 41 respectively and in the space between the air casing walls inner and outer annular flame tube walls 42 and 43 respectively. The walls 42, 43 are made in a number of sections and have adjacent their downstream ends large apertures 44 through which air flowing in the spaces between the inner walls 40, 42 and outer walls 41, 43 can enter the combustion space afforded between the flame tube walls 42 and 43.

The upstream edges of the flame tube walls 42, 43 are spaced apart to provide an air entry 45 to between these walls. Secured to the inner surface of the outer flame tube wall 43 and to the outer surface of the inner flame tube wall 42 there are annular air-flow dividing members 46, 47 respectively.

Each of the members 46, 47 is generally shaped to conform to the adjacent portions of the adjacent flame tube wall 43, 42 respectively and each is provided at its downstream end with a flange 48 by which it is attached to the associated flame tube wall and at its upstream end with an inturned flange 49 extending parallel to the axis of the combustion equipment, these flanges 49 being spaced apart to form an air entry to between the annular members 46, 47. The annular members have formed in them just upstream of the flanges 48 a ring of holes 50 by which air flowing between the annular members 46, 47 and the adjacent flame tube walls 43, 42 can enter the combustion space of the flame tube.

Extending radially between the annular members 46, 47 and secured to the downstream ends of the inturned flanges 49, there is an annular member of such section as to have a circumferential ridge 51 projecting downstream, which ridge closes the end of the passage between the flanges 49, and radially on each side of the ridge circumferential downstream facing troughs 52. The sides of the ridge are formed with rings of holes 51a.

Fuel is injected into the passage between the flanges 49 by means of an injector 53 fed with liquid fuel by a fuel supply pipe 54, and fuel is injected into the combustion space of the flame tube at a position just downstream of the annular members 46, 47 by means of an injector 55 having an upstream delivering fuel orifice 56 and a downstream delivering fuel orifice 57.

The fuel injector 53, the air passage between the flanges 49 and the annular member 51, 52 together afford first air and fuel injection means and the air/fuel mixture entering the upstream region 58 of the combustion space from the first air and fuel injection means partakes of a swirling motion as indicated by arrows 59, in which the mixture first travels from the local centre line of the flame tube towards the annular members 46, 47, then travels upstream, then travels towards the local centre line and finally travels downstream. It is arranged that the air and fuel introduced by the first air/fuel injection means are in their stoichiometric ratio.

The holes 50 in the annular members 46, 47 and the fuel injection orifice 56 together afford second air/fuel injection means which produce in a region 60 of the combustion space which is just downstream of the region 58, a swirling motion which is counter to the swirling motion in the region 58, that is the gases flow from the holes 50 towards the local centre line of the flame tube, then in the upstream direction, then away from the local centre line towards the annular members 46, 47 and then in the downstream direction. The fuel from the fuel orifice 57 mixes with the combustion products from the combustion zones 58, 60 and is burnt with the excess air therein and with air entering the combustion space through the apertures 44, which also mixes with the combustion gases to cool them.

Referring now to Figure 3, there is shown an arrangement which is similar to that shown

in Figure 1 and similar parts in these figures are given the same reference numerals. However, instead of the spider member 24, 25 and fuel injectors 26, 28 there is provided to encircle the tube 21 adjacent its its waist an annular trough member 62 which is concave on its downstream side and a single fuel injector 63 is provided for supplying fuel to both combustion regions. The injector 63 has a peripheral ring of fuel orifices 64 which inject fuel into the air flowing into the cap 22 prior to its entry into the upstream combustion space 65 through the holes 23 in the cap member and the injector 63 delivers fuel from its end 66 through an aperture in the cap member into the combustion region 67.

As in the construction of Figure 1 the combustion mixtures in the regions 65 and 66 have counter swirls as indicated by the arrows 33 and 35.

In each of the constructions above described it is found that by arranging combustion to take place in separate and adjacent regions in which counter swirls are produced, the combustion efficiency of the apparatus is improved.

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824,306 PROVISIONAL SPECIFICATION
I SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig.1.

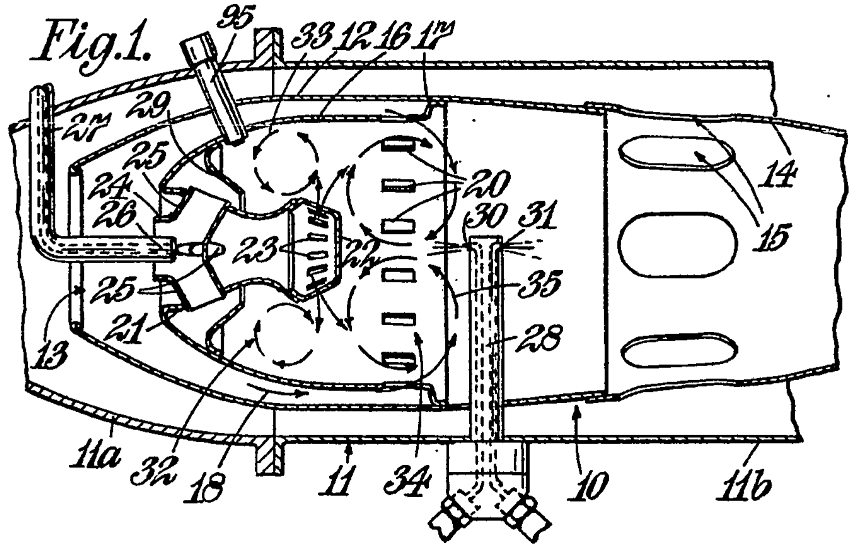

Fig.2.

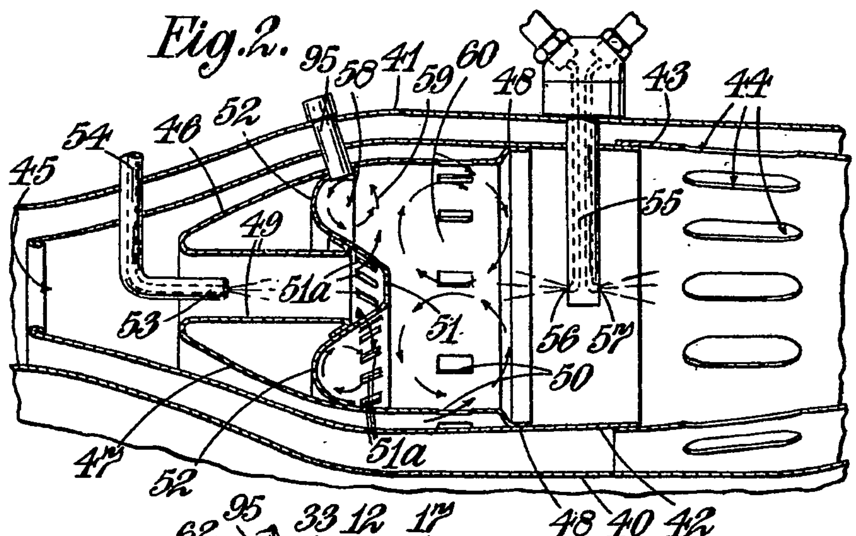

Fig.3.

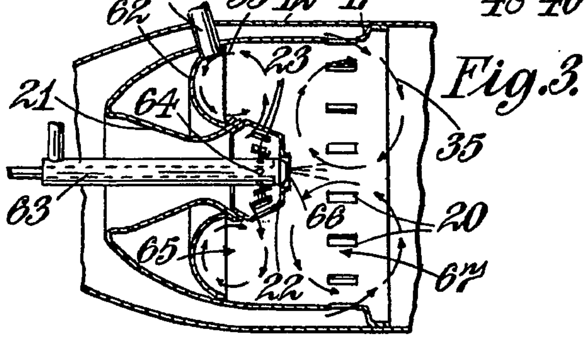

Fig.4.

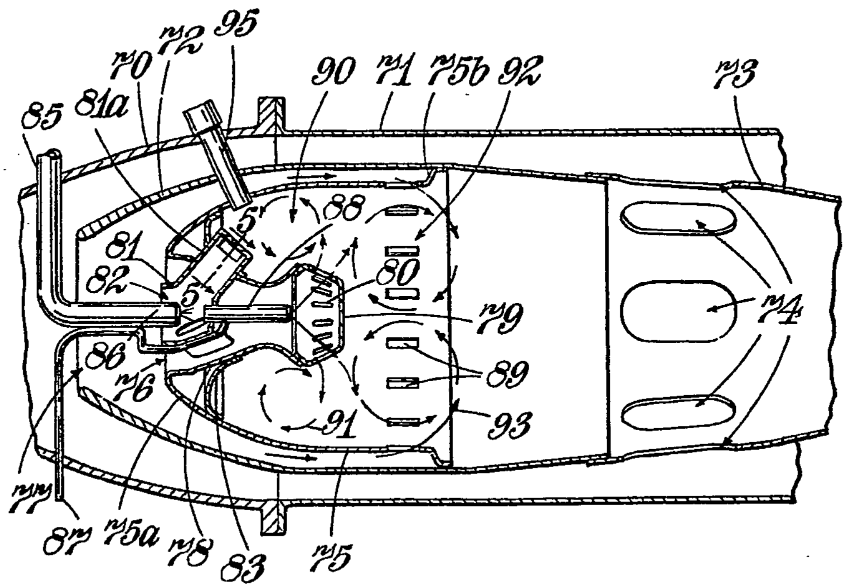
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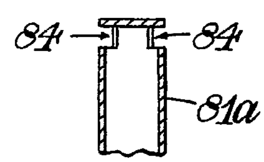
Fig.5.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